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1.	Your reference	**P/61299.GBA/MAD**
2.	Patent application number *(The Patent Office will fill in this part)*	**9904669.0** - 1 MAR 1999
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	Marconi Electronic Systems Ltd The Grove Warren Lane Stanmore Middlesex HA7 7LY
	Patents ADP number *(if you know it)*	760794800 1
	If the applicant is a corporate body, give the country/state of its incorporation	**ENGLAND**
4.	Title of the invention	Head tracker system
5.	Name of your agent *(if you have one)*	C F Hoste
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	**GEC PATENT DEPARTMENT WATERHOUSE LANE CHELMSFORD ESSEX CM1 2QX**
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Description	12
Claim(s)	3
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Priority documents	0
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Statement of inventorship and right to grant of a patent (Patents Form 7/77)	0
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C F Hoste

Date 1st March 1999

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Head Tracker System

This invention relates to a head tracker system and more especially, although not exclusively, to a head tracker system for use in an aircraft, helicopter or other vehicle in which an operator is provided with a helmet mounted display.

Head tracker systems are well known and operate to determine a user's head orientation and position relative to a fixed datum. Originally these systems were developed for use in military aviation but have recently found applications in virtual reality systems.

Since the earliest days of military aviation, pilots have, not surprisingly, preferred to navigate and aim weapon systems whilst looking up and out of the cockpit. This lead to the evolution of the head-up display (HUD) which displays useful symbology which is appropriately referenced to the outside world (often termed "ground stabilised"). HUDs generally have a viewing angle of thirty degrees or less and can consequently only be viewed when the pilot is looking in a generally forward direction. To increase the field of regard (that is the total volume of space over which the pilot can view the symbology and includes the pilot moving his head) helmet mounted displays (HMD) have evolved which essentially comprise a HUD which is mounted on the pilot's helmet within his field of view. In order that ground stabilised symbols or imagery are presented to the pilot in the correct orientation with respect to the outside world, the symbol generator of the HMD must know in all three axes, that is elevation,

azimuth and roll, where the pilot's head is directed in relation to the outside world. This is achieved by determining (a) the angular orientation of the pilot's head with respect to the aircraft reference axes and (b) the orientation (attitude) of the aircraft with respect to the outside world. The former requirement led to the development of head tracker systems. HMDs operate in conjunction with the head tracker system which determines the angular orientation of the user's head with respect to the aircraft axes to ensure that the displayed information is correctly aligned in space or is accurately superimposed against objects in the outside world.

Typically, a head tracker system comprises a head mounting, most commonly a helmet, which is attached to the user's head and a sensor system for determining the angular orientation of the helmet relative to a fixed reference datum. Although strictly speaking a head tracker system actually tracks the orientation of the head mounting and not the user's head, it provides an accurate measure of the user's head orientation provided the head mounting remains in a fixed orientation relative to the user's head.

The reference datum is typically three axes which pass through a known point on the vehicle or aircraft frame. A number of sensor systems have been proposed. For example, early tracking systems used mechanical linkages between the helmet and the vehicle and, whilst such systems are relatively accurate, they were cumbersome, restricted the user's movement and posed particular problems during ejection from an aircraft. To overcome this problem a number of other systems have been developed which do not involve any mechanical linkage between the head mounting and the

aircraft, such as for example those using magnetic, optical, acoustic, inertial and other types of sensor systems. In the case of a magnetic sensor system a magnetic field generator located in the aircraft cockpit generates three orthogonal alternating, or pulsed, magnetic fields along a respective fixed reference axis. These fields are detected by sensors on the helmet (commonly three search coils which are mounted in an orthogonal relationship to each other) and the signals convoluted with the earth's magnetic field to determine the user's head orientation. It has also been proposed to use inertial systems which use gyroscopes and accelerometers to measure the angular velocity and acceleration of the helmet mounting about each respective axis. Optical systems have also been proposed in which the helmet carries a number of visually distinctive physical markings which are detected by a camera which is fixed in a known orientation within the cockpit. The video image captured by the camera is processed electronically to determine when one of the markings is within the camera's field of view and where it is within the field of view and from this data the user's head orientation is calculated.

A particular requirement of head tracker system for use in military aviation is high accuracy coupled with a fast dynamic response as the pilot's head movements are often extremely rapid; typically these can be greater than two hundred degrees per second. These two requirements are often mutually exclusive and the known tracker systems are a compromise in achieving these objectives. For example, although inertial systems based on gyroscopes have a very fast dynamic response, the accuracy of these systems is limited by drift over extended periods of operation. Tracker

systems which are based on magnetic sensors, although accurate, do not provide a fast enough dynamic response and optical systems are neither fast enough or accurate enough due to the large amount of electronic processing required. The latency in data processing in most tracker systems is further compounded by the additional lag which is introduced by the filtering needed to minimise the effect of noise on the often very low levels of signals being detected. In an attempt to overcome these problems it has been proposed to have tracker systems which are hybrid systems and which involve a combination of two of the above systems such as, for example, an inertial system to provide the dynamic response which is supplemented by a magnetic system for long term accuracy.

The present invention has arisen in an endeavour to provide a system which, at least in part, overcomes the limitations of the known head tracker systems.

According to the present invention a head tracker system for determining a user's head orientation relative to a datum comprises: a head mounting for attachment to the user's head; an optical sensor located at a known fixed point relative to the head mounting; a plurality of marking generators each associated with a respective known point which is fixed relative to the datum wherein each marking generator is operable to generate its own unique visually distinctive marking which is collimated and whose axis is predetermined and passes through the respective known point associated with the marking generator, an optical correllator for optically correllating the visual image from the optical sensor with an optical image representative of one of said markings

and means for determining the orientation of the head mounting using the output from the optical correllator when it detects there is correllation between the images.

It will be appreciated that the location of the marking generators and optical sensor can be interchanged and thus according to a second aspect of the invention a head tracker system for determining a user's head orientation relative to a datum comprises, a head mounting for attachment to the user's head, a plurality of marking generators each associated with a respective known point which is fixed relative to the head mounting, wherein each marking generator is operable to generate its own unique visually distinctive marking which is collimated and whose axis is predetermined and passes through the respective known point associated with the marking generator, an optical correlator for optically correlating the visual image from the optical sensor with an optical image representative of at least one of said markings and means for determining the orientation of the head mounting using the output from the optical correlator when it detects there is correlation between the images.

Unlike the known tracker systems which use electronic processing (e.g. fast Fourier transforms), the tracker system of the present invention has a fast dynamic response as a substantial part of the processing is carried out optically.

Advantageously the, or each, recognisable marking comprises a spatial pattern such as for example, a cross, circle, diamond, triangle or other simple pattern. In addition or alternatively the, or each, distinctive marking can be defined in part at least by the

wavelength of light, or by modulating the light produced by the marking generator.

In a preferred implementation the optical sensor comprises a video camera, such as a charge coupled device (CCD), for capturing the visual image and producing an electrical signal representative of it and the tracker further comprises means for converting the electrical signal back to a visual image. Such an arrangement enables the optical correlator to be mounted remotely from the head mounting.

Preferably the optical correlator is a Vander Lugt or joint transform type correlator and the means for converting the electrical signal back to a visual image comprises one of the spatial light modulators of the optical correlator. Advantageously the optical correlator is operable to sequentially optically correlate the visual image from the optical sensor with an optical image representative of each of the markings. As an alternative, or in addition, further optical correlators can be provided each of which is dedicated to detecting one or more of the markings.

A head tracker system in accordance with the invention will now be described by way of example only with reference to the accompanying drawings in which:

Figure 1 is a schematic representation of a head tracker system in accordance with the invention; and

Figure 2 is a schematic representation of the optical correllator of the head tracker of

Figure 1.

Referring to Figure 1 there is shown a head tracker system for use in a fixed wing aircraft which comprises a helmet 2 which constitutes a head mounting for attachment to a pilot's head. In a known manner the helmet 2 is provided with a visor 4 and internally the helmet is provided with a helmet mounted display (HMD) device (not shown) which is arranged to project a display onto a partially reflective inner surface of the visor 4 so that the display is superimposed upon at least a part of the view seen by the pilot through the visor 4. In an alternative arrangement the HMD device can project a display onto discrete eye pieces which are located within the line of sight of the pilot. As is known the symbology displayed on the HMD is generated by a symbol generator 6 which is located within the aircraft. The signals used to drive the HMD are passed to the helmet along an umbilical cord 8 which is provided with a quick release connector arrangement 10 fixed inside the cockpit.

A miniature charged coupled device (CCD) video camera 12 is rigidly mounted to the helmet 2. The axis 14 of the field of view of the video camera is accurately aligned to a set reference axis within the helmet 2. Typically, although not necessarily, the axis is set to correspond to the forward looking direction of the pilot. The camera 12 is focussed at infinity (in the context of the present invention infinity, in practical terms, corresponds to four metres or more) or slightly less to compensate for any effect the canopy windshield 16 may have. The video output from the camera 14 is thus representative of the view seen by the pilot minus the symbology generated by the

HMD. This video signal is passed down the umbilical cord 8 to a video processor 18 where it is combined with the symbology from the HMD symbol generator to form a facsimile of the view seen by the pilot. This composite image is recorded on a video recorder 20 and used after the flight to evaluate the pilot's performance. The resolution of the camera is of VGA standard, that is six hundred and forty five by four hundred and eighty pixels, and can be monochrome or colour.

Mounted around the cockpit at fixed known locations are five marking generators 24a to 24e. Each marking generator 24, which comprises a light emitting diode and collimator produces a collimated beam of light containing a symbol or pattern which is unique to the generator. For example 24a produces a circle, 24b produces a cross, 24c produces a diamond and so forth. As described each marking generator 24 produces its own unique symbol and this is accurately aligned along a predetermined axis 25 which passes through a point which is accurately known relative to a set fixed reference datum (x,y,z) 26. As will be appreciated the marking can be any form of visually distinctive marking and the only requirement is that the generator can be unambiguously identified from the spatial pattern it generates. Thus, each generator produces a unique visually distinctive pattern which defines a known location.

In an alternative arrangement it is envisaged to additionally define the marking in terms of the wavelength of the light it produces or by modulating the light produced by the generator. Such an arrangement enables a greater number of points to be identified using only a limited number of spatial patterns, for example, one marking

generator can generate a red cross, another an orange cross etc.

As will now be described, the marking generators 24a-e, in conjunction with the camera 12, are used to determine the position and orientation of the helmet 2 relative to the aircraft reference datum 26.

The video signal from the camera 12 is also applied to one input of an optical correlator 28 which processes the information to identify when one of the markings passes through the field of view of the camera 12. The operation of the optical correlator 28 is described below. When the optical correlator 28 detects and identifies which marking has passed through the camera's field of view the system knows that the camera 12 and hence the helmet 2 were oriented in a known direction when that video frame was captured. From this information the position of the helmet 2 can be determined by a processor 30 and the movement of the pilot's head relative to the reference datum 26 determined and tracked.

Referring to Figure 2 there is shown a schematic representation of the optical correlator 28, which is of a known type, often termed a Vander Lugt correlator. As is known the correlator 28 comprises an input spatial light modulator (SLM) 32 for inputting the image captured by the camera 12, a reference SLM 34 for inputting the image with which the first image is to be optically correlated; two polarising beam splitters 36, 38, two half wave plates 40, 42, four Fourier lenses 44, 45, 46, 48, 50, a laser diode 52, a beam expander 54 and a CCD camera 56 for measuring the output

of the correlator 28. The operation of optical correlators is well known and accordingly their operation will not be discussed in detail.

In operation the processor 30 has stored images (in the form of a video signal) which are representative of each of the visually distinctive markings and it applies each of these sequentially the reference SLM 34 such that the correlator 28 optically correlates each frame captured by the video camera 12 with an image representative of each of the possible markings. As is known the two SLM's 32, 34 optically encode the video signals onto a coherent collimated laser beam generated by the laser diode 52 and beam expander 54. These coherent optical images are Fourier transformed by the Fourier lens 44, 46 at its focal (Fourier) plane. Since the images created are coherent with each other, they constructively interfere where they are the same resulting in a set of correlation peaks which are in the form of spots of light whose location indicates where the two images are the same and whose intensity shows how similar the images are. This set of correlation peaks is detected by the CCD camera 56 once they have been reverse transformed by the Fourier lenses 48, 50. The output of the camera 56 is used by the processor 30 to detect when one of the markings passes through the field of view of he camera 12 and which marking generator produced it. From this information the processor can determine the orientation of the helmet 2. Since a large proportion of the processing is carried out optically the tracker system has an extremely fast dynamic response.

It will be appreciated that the present invention is not restricted to the specific

embodiment described and that modifications can be made which are within the scope of the invention. For example, in an alternative arrangement the video camera can be mounted in the cockpit and the marking generators mounted on the helmet. In a preferred arrangement two cameras are used, one on each side of the helmet and a second optical correlator used to correlate its output with the reference symbols. Whilst the use of a video camera has been described, it will be appreciated that other forms of optical sensor can be used such as position sensitive devices. Furthermore it will be appreciated that the number and type of marking generators can be varied, provided that each produces a collimated image which is visually distinctive and which can unambiguously identified. Accordingly in yet a further embodiment one or more of the markings can be generated using a head-up display in place of or in addition to the separate marking generators. In the embodiment described the output of the video camera 12, which comprises an electrical video signal, is passed down the umbilical cord 8 to the optical correlator 28, thereby eliminating the need to mount the correlator on the helmet 2. With such an arrangement the processing speed of the system, whilst quick, is limited to the frame rate of the camera, that is two hundred and twenty frames per second. In an alternative tracker system the optical correlator could be mounted on the helmet or the umbilical cord 8 could include one or more optical filters to eliminate the need to process video signals. To further increase the dynamic response it is also envisaged to provide one or more optical correlators each dedicated to one or two markings such that substantially continuous optical processing can be achieved. It will be further appreciated that other forms of optical correlator can be used such as a joint transform type which has the advantage of only requiring a single

spatial light modulator (SLM) onto which the input and reference images can be displayed side by side. Although the tracker system has been described in relation to a fixed wing aircraft it can be applied equally to other vehicles or any application where it is required to track a user's head movement relative to a fixed datum.

Claims

1. A head tracker system for determining a user's head orientation relative to a datum comprising: a head mounting for attachment to the user's head; an optical sensor located at a known fixed point relative to the head mounting; a plurality of marking generators each associated with a respective known point which is fixed relative to the datum, wherein each marking generator is operable to generate its own unique visually distinctive marking which is collimated and whose axis is predetermined and passes through the respective known point associated with the marking generator, an optical correllator for optically correllating the visual image from the optical sensor with an optical image representative of at least one of said markings and means for determining the orientation of the head mounting using the output from the optical correllator when it detects there is correllation between the images.

2. A head tracker system for determining a user's head orientation relative to a datum comprising: a head mounting for attachment to the user's head; a plurality of marking generators each associated with a respective known point which is fixed relative to the head mounting, wherein each marking generator is operable to generate its own unique visually distinctive marking which is collimated and whose axis is predetermined and passes through the respective known point associated with the marking generator, an optical correlator for optically correlating the visual image from the optical sensor with an optical

image representative of at least one of said markings and means for determining the orientation of the head mounting using the output from the optical correlator when it detects there is correlation between the images.

3. A head tracker according to Claim 1 or Claim 2 in which the, or each, visually distinctive marking comprises a spatial pattern.

4. A head tracker system according to any one of Claims 1 to 3 in which the, or each, visually distinctive marking is defined in part at least by the wavelength of light produced by the marking generator.

5. A head tracker system according to Claim 3 or Claim 4 in which the or each visually distinctive marking is defined in part at least by modulating the light produced by the marking generator.

6. A head tracker system according to any preceding claim in which the optical correlator is operable to sequentially, optically correlate the visual image from the optical sensor with an optical image representative of each of the markings.

7. A head tracker system according to any preceding claim in which the optical sensor comprises a video camera for capturing the visual image and producing an electrical signal representative of it and connecting the electrical signal back to a visual image.

8. A head tracker system according to any preceding claim and further comprising a second optical sensor located at a second known fixed point relative to the head mounting.

9. A head tracker system according to any preceding claim in which the optical correlator is a Vander Lugt type correlator.

10. A head tracker system according to any one of Claim 1 to 8 in which the optical correlator is of the joint transform type.

11. A head tracker system substantially as hereinbefore described or substantially as illustrated by way of reference to Figure 1 of the accompanying drawings.

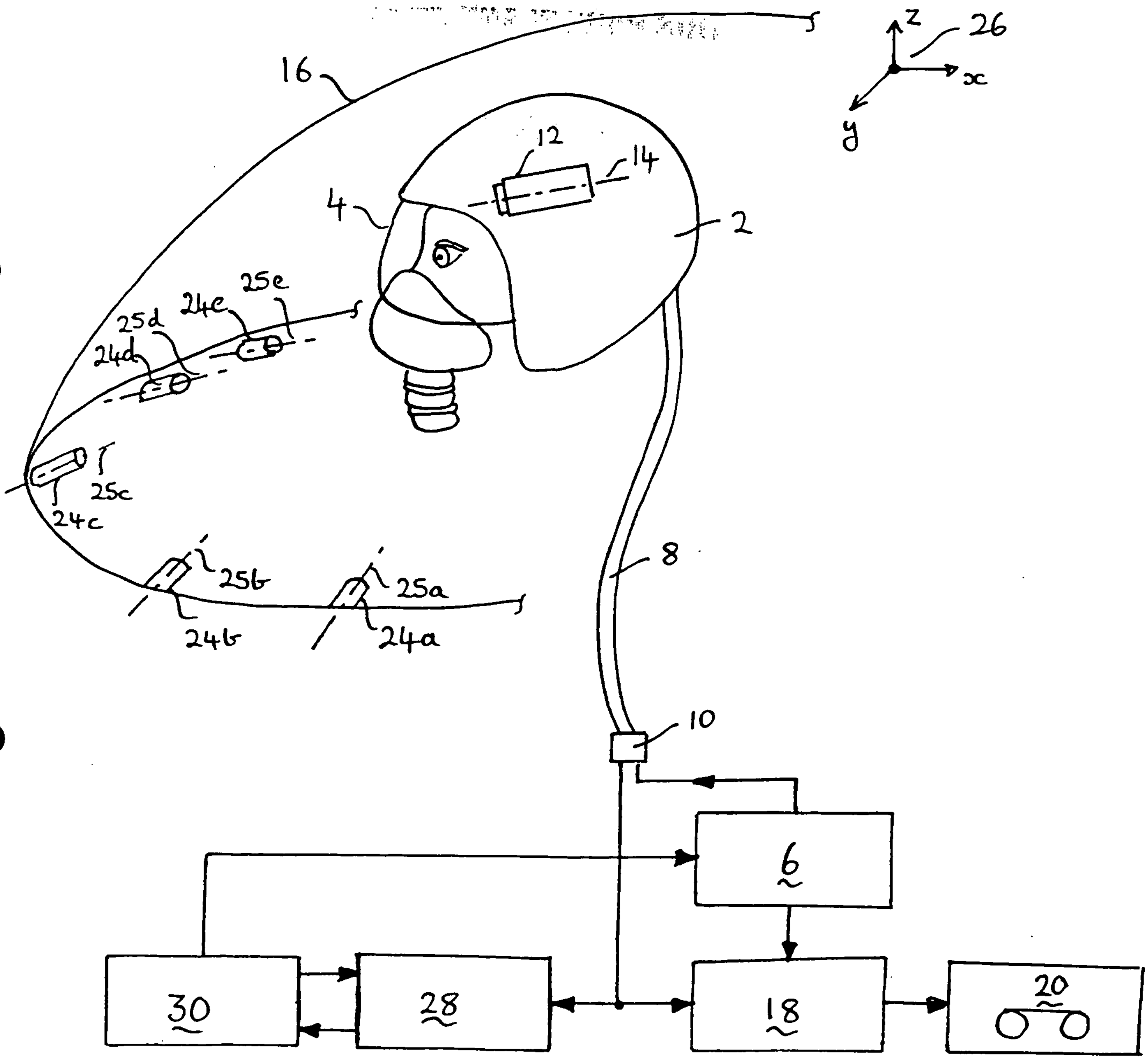

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Figure 1.

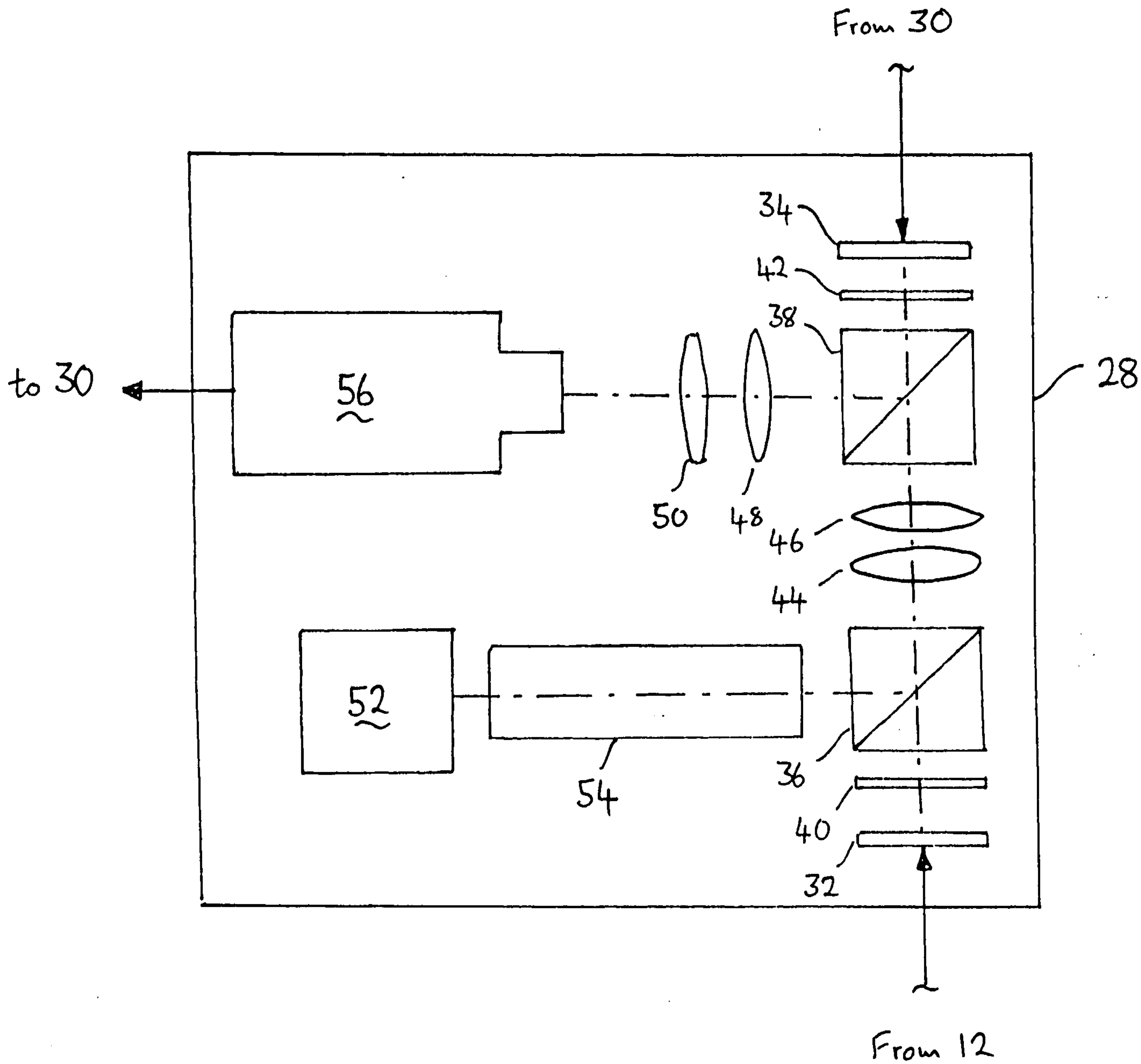

Figure 2

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